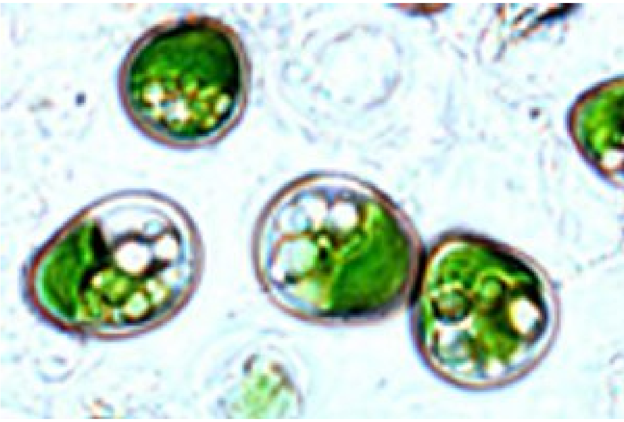
BOISE STATE UNIVERSITY

Nutrient Sequestration using Algae with AD Systems

Kevin Feris (BSU), Maxine Prior (UI), Erik R. Coats (UI), Erin Searcy (DOE), Donna Post Guillen (INL), Sam Alessi (INL)

- USDA AFRI (Agriculture and Food Research Initiative)
  - Integrated Approaches to Climate Adaptation and Mitigation in Agroecosystems
  - Goals:
    - Adaptation
    - Mitigation
    - Reduce energy use, nutrient impacts, greenhouse gas production
    - Increase carbon sequestration

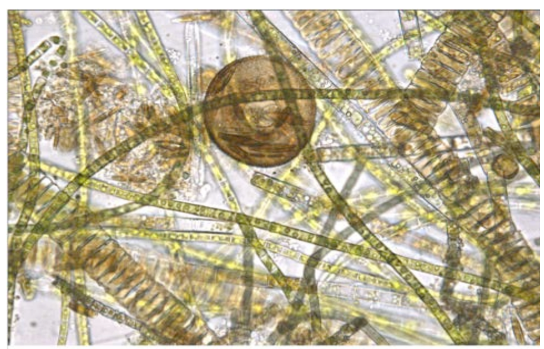
- CH_4 and CO_2 emissions from dairy operations constitute ~2.5% of annual U.S. greenhouse gas (GHG) emissions
- Anaerobic digestion (AD) can reduce dairy CH_4 emissions while producing electricity, but…
  - Dairy ADs can be constrained economically
  - ADs also emit large quantities of CO_2 (another GHG)
- To decrease the Carbon footprint of dairies:
  - Sequester AD effluents (CO_2, nitrogen, phosphorus) by producing algae



Our Goal: Quantify and optimize algal C-sequestration and nutrient treatment from processed manure effluent streams

AD effluent

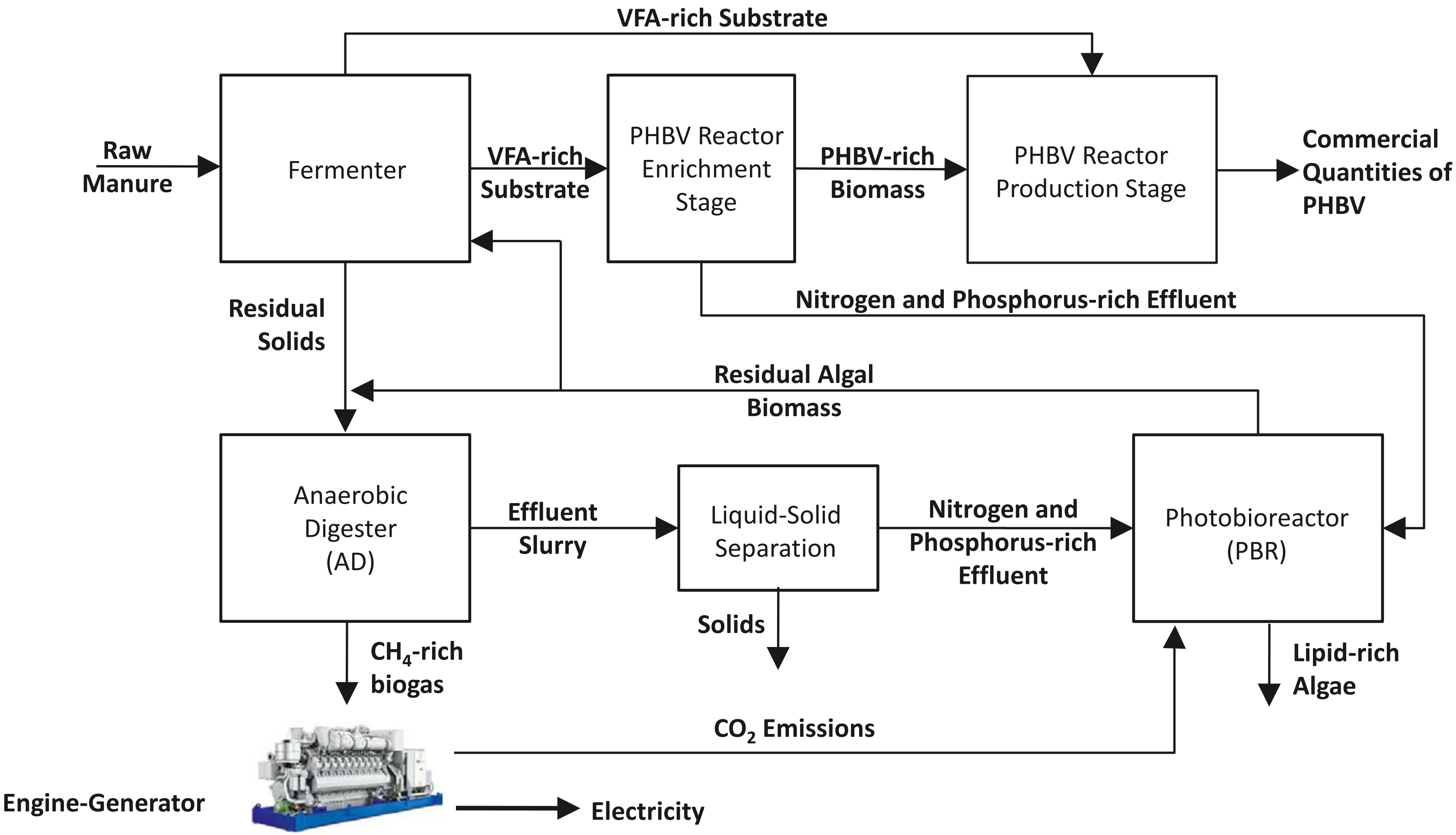
PHBV effluent



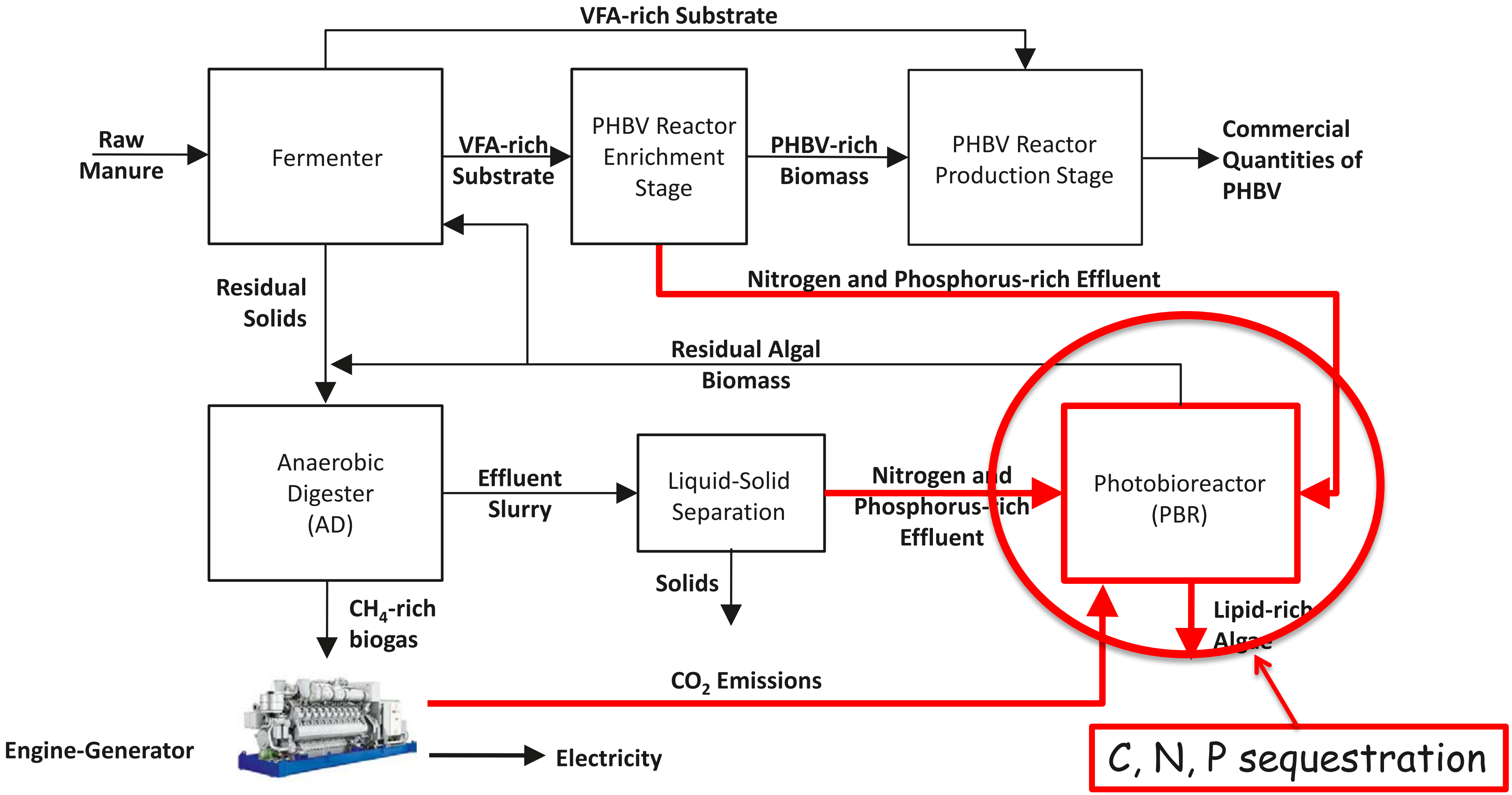
Wastewater algae consortium

Algal biomass: C, N, P sequestered, value added commodity

Our Integrated Process



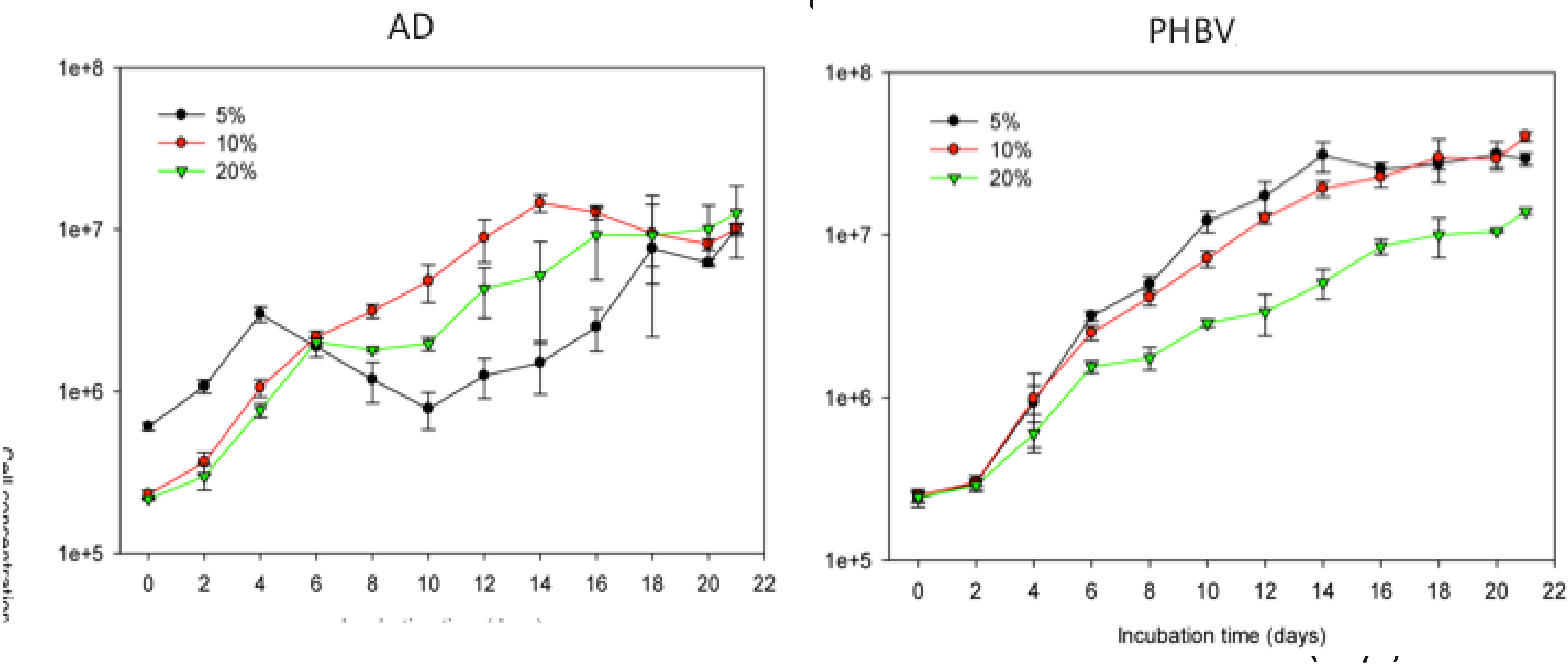
Our Integrated Process



Characteristics of AD and PHBV reactor effluents

	Digested Manure Effluent ($mg \cdot L^{-1}$)	Polyhydroxyalkonoate Reactor Effluent ($mg \cdot L^{-1}$)
Organic Acids		
Acetate	456.2	ND
Propionate	155.6	ND
Butyrate	96.5	ND
Valerate	41.1	ND
isoValerate	9.8	ND
Caproate	2.8	ND
Chemical Components		
Total dissolved nitrogen (N)	1226.0	499.5
Ammonia (NH_3-N)	760.8	59.2
Nitrate (NO_3^--N)	<10	361.2
Total dissolved phosphorus (P)	96.2	33.3
Chemical oxygen demand (COD)	12,744.4	5,575.2
pH	8.3	8.4
Bacteria Load ($CFU \cdot mL^{-1}$)	2.06E+06	2.66E+03
Absorbance @ 680 nm	0.650	0.195

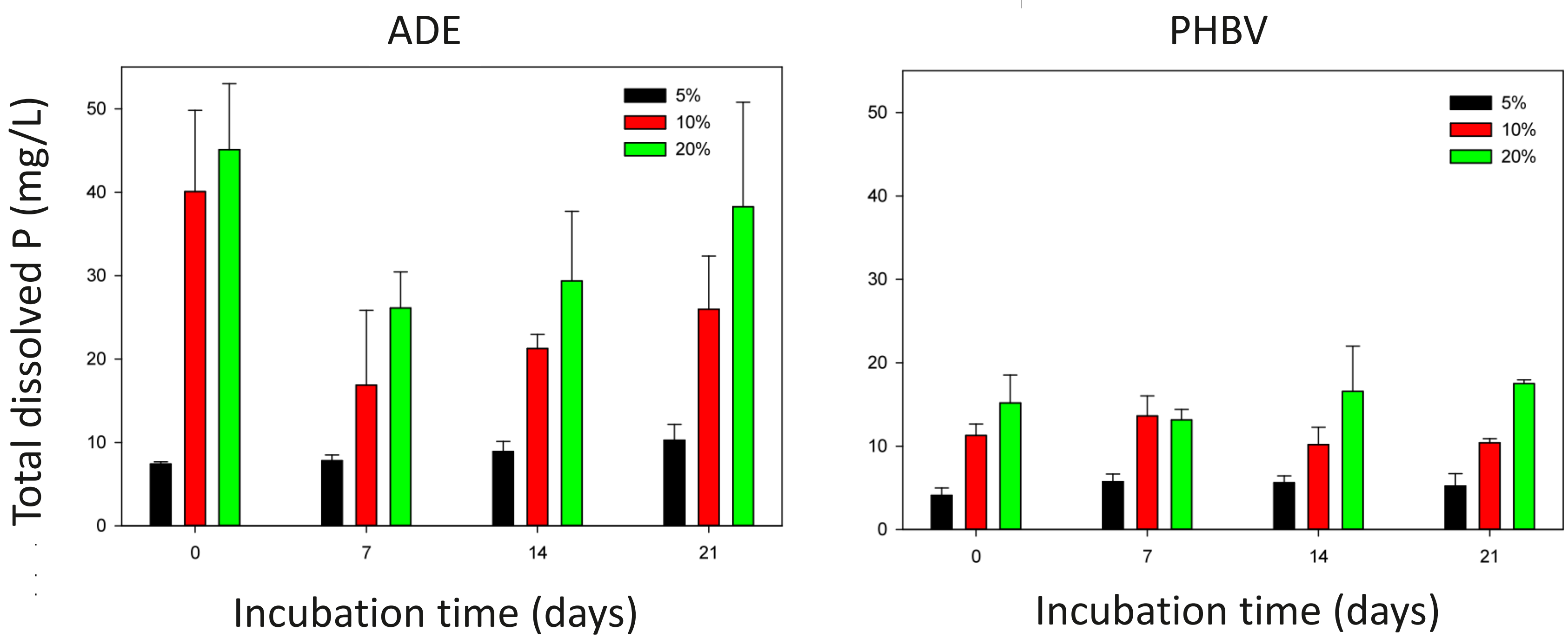
Phototrophic production by *C. vulgaris* grown in AD and PHBV efflu



5 and 10% PHBV: highest growth rates, longer exponential growth phase

Result: 3x to 4x the cell yield observed in the same concentration of AD effluent.

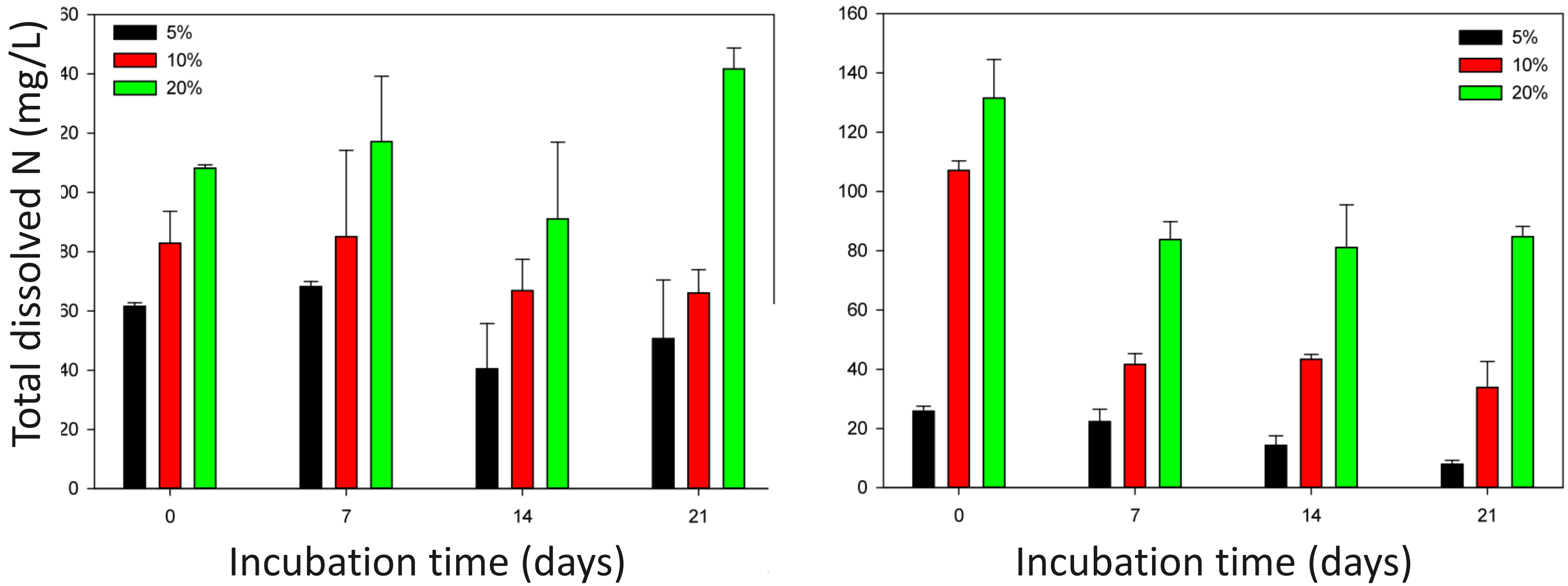
Phosphorus removal by algal cultures grown on AD and PHBV reactor effluent



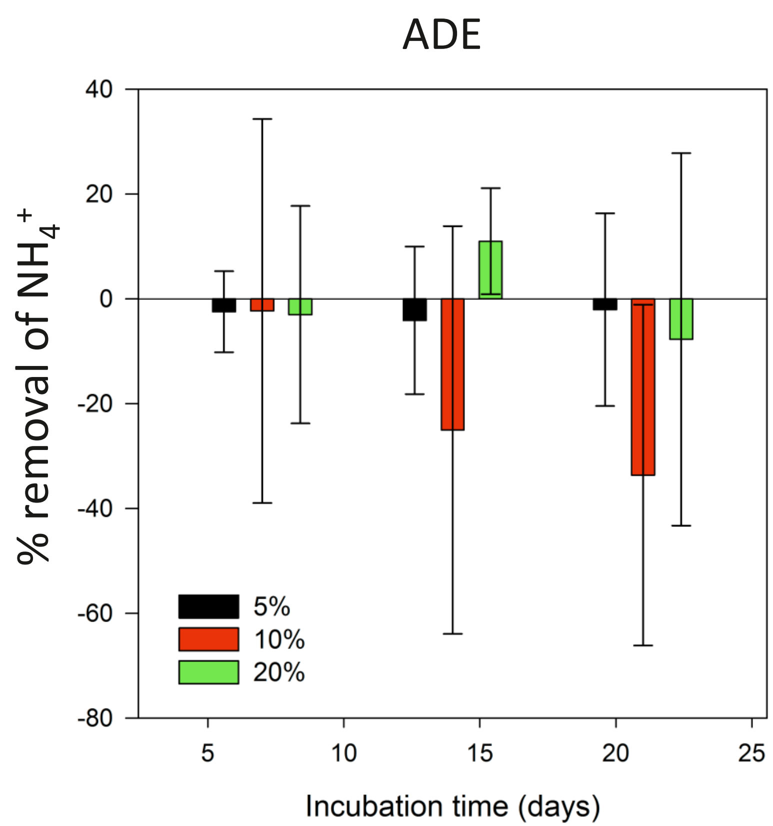
Nitrogen removal by algal cultures grown on AD and PHBV reactor effluent

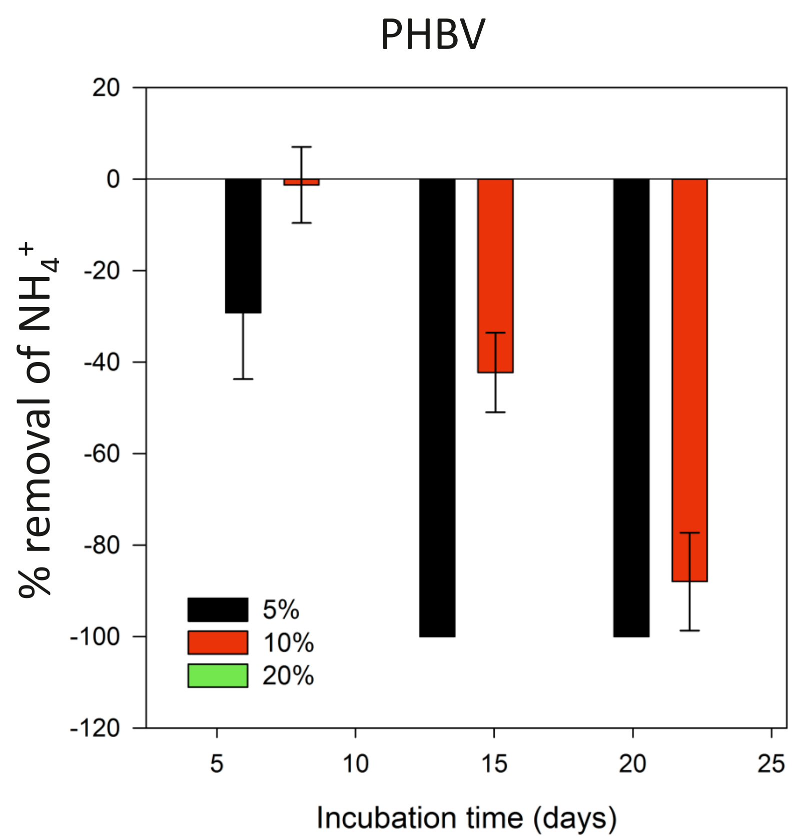
ADE

PHBV



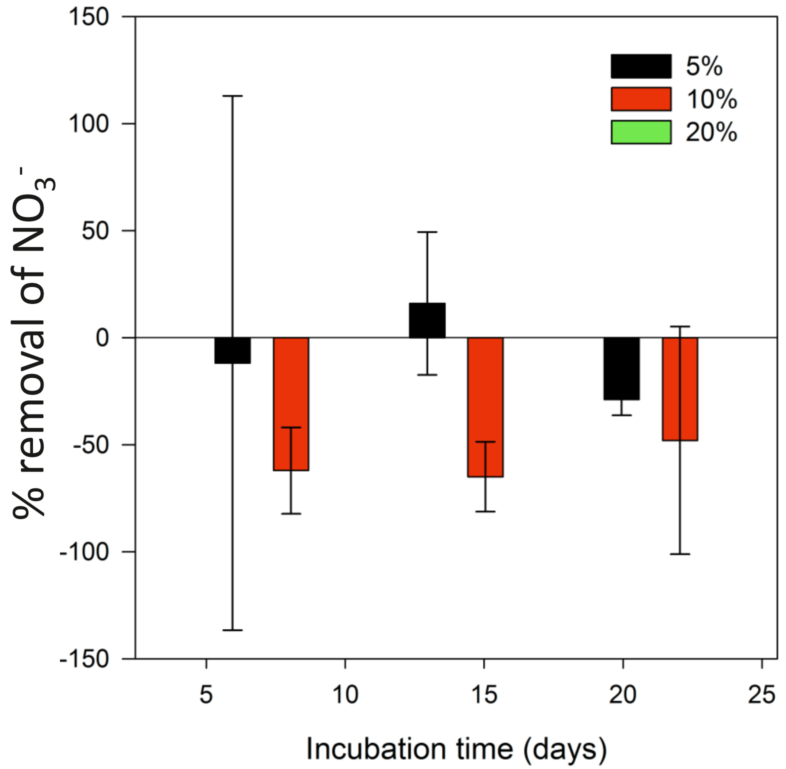
N-sequestration is dependent on the form of N and effluent concentration: **Removal of NH_4^+**



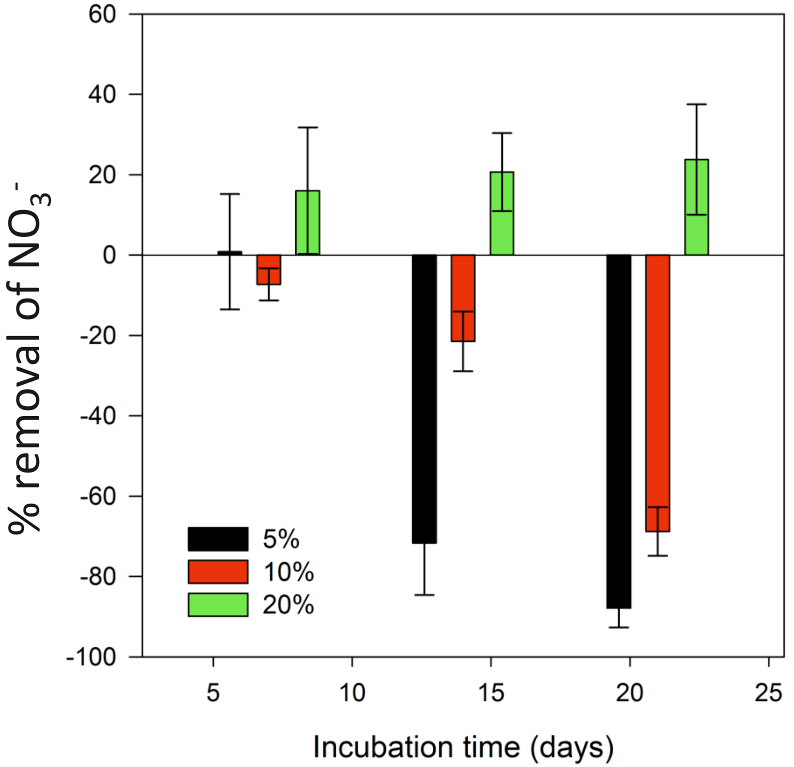


N-sequestration is dependent on the form of N and effluent concentration: **Removal of NO_3^-**

ADE



PHBV



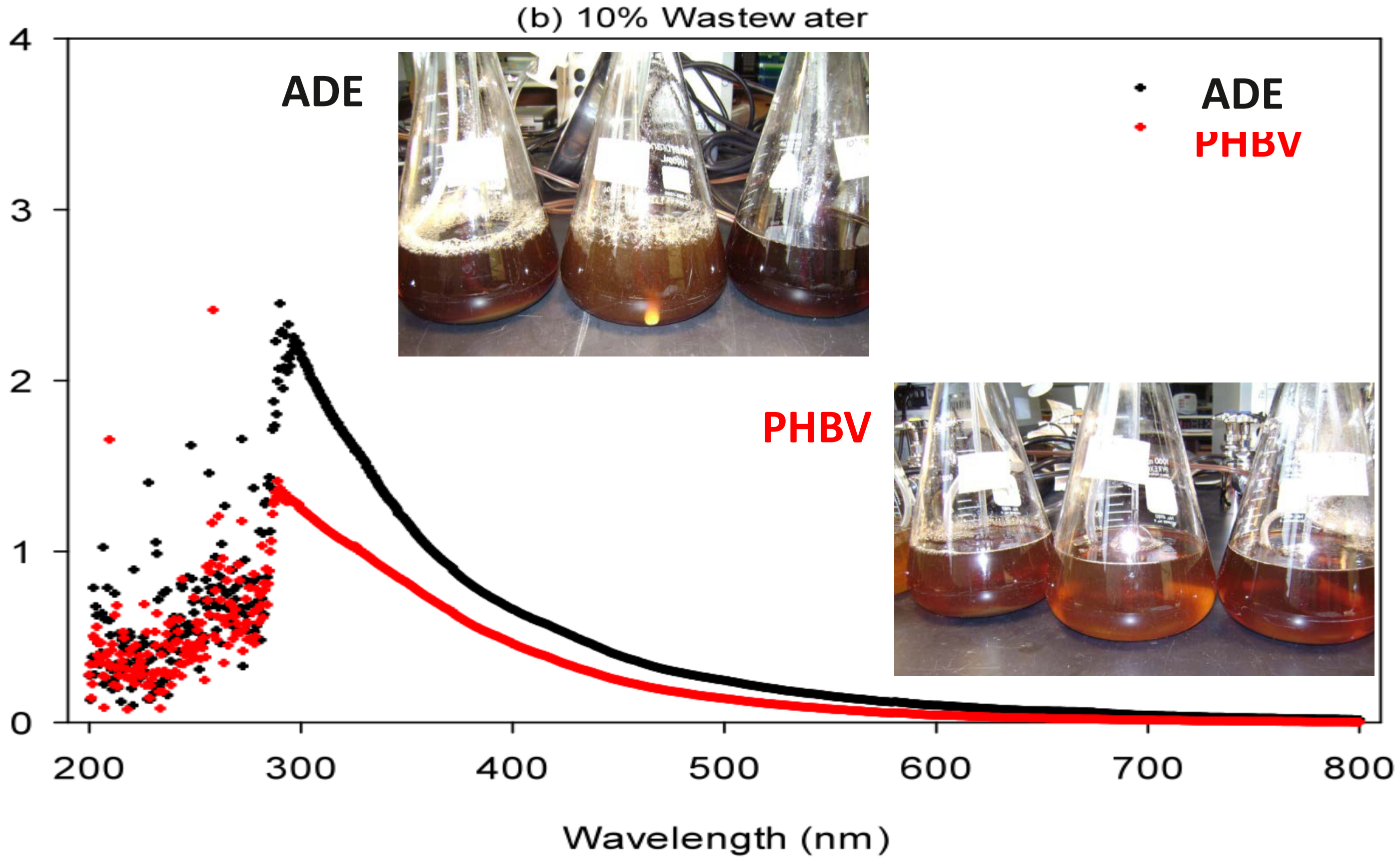
Nutrient removal rates (AD vs. PHBV effluent)

	Anaerobic Digester Effluent			PHBV Effluent		
	5%	10%	20%	5%	10%	20%
Rate of change of dissolved nutrients in solution over 21 days ($mg \cdot L^{-1} \cdot day^{-1}$)						
Dissolved Nitrogen (TDN)	0.52 (0.89)	0.95 (0.90)	-1.57 (0.52)	0.85 (0.12)	3.44 (0.73)	2.13 (0.59)
Ammonia (NH_3-N)	0.04 (0.34)	0.78 (0.87)	0.38 (1.48)	N.D.	0.23 (0.00)	0.50 (0.06)
Nitrate (NO_3-N)	N.D.	0.01 (0.03)	0.07 (0.07)	0.65 (0.03)	1.41 (0.12)	-0.77 (0.38)
Dissolved Phosphorus (TDP)	-0.14 (0.10)	0.67 (0.23)	0.33 (0.64)	0.05 (0.09)	-0.04 (0.06)	0.11 (0.17)

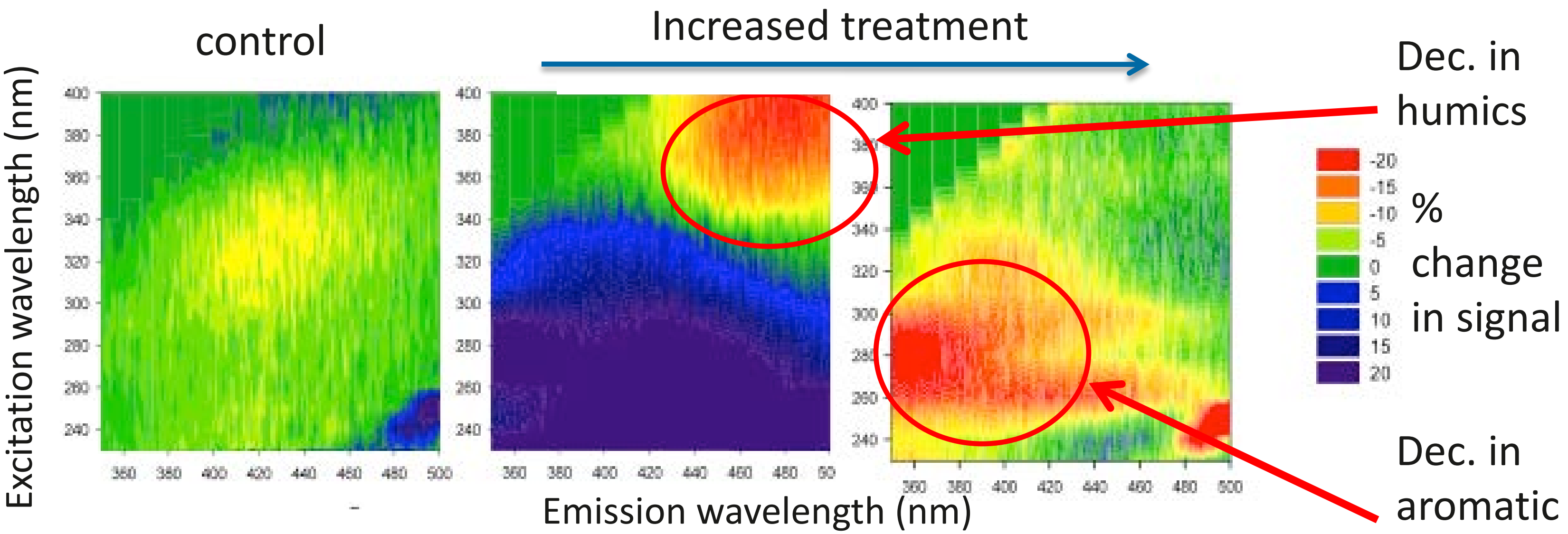
PHBV: faster N removal

ADE: faster P removal

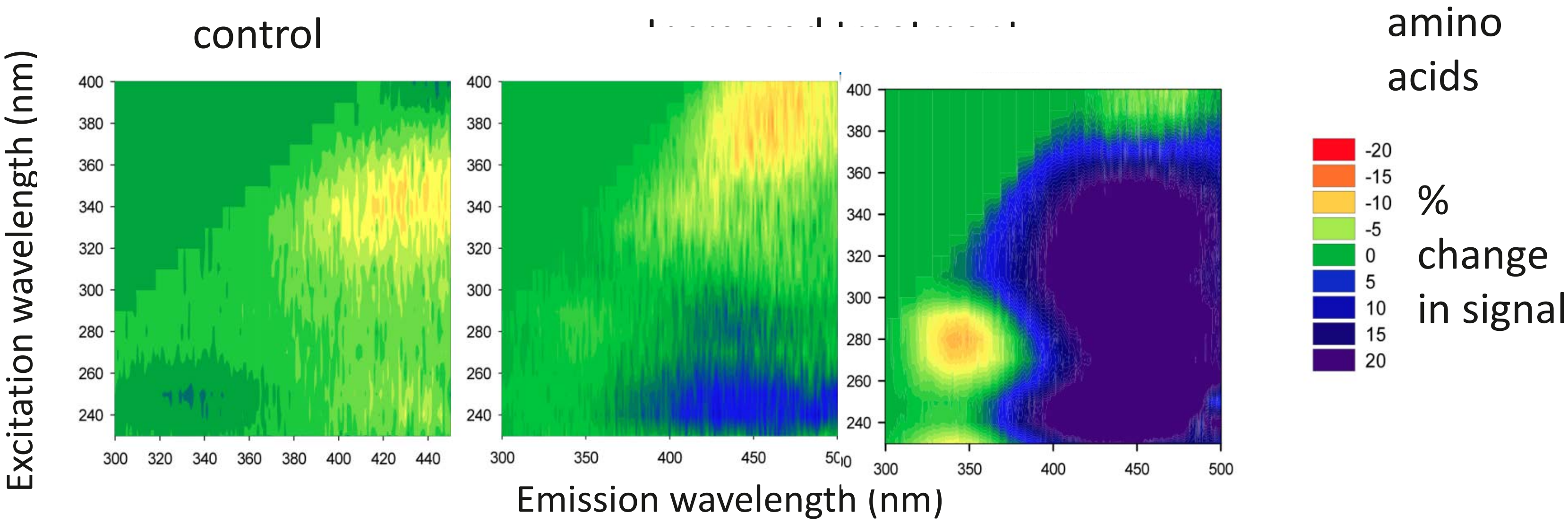
Optical properties of AD effluent and PHBV reactor effluent



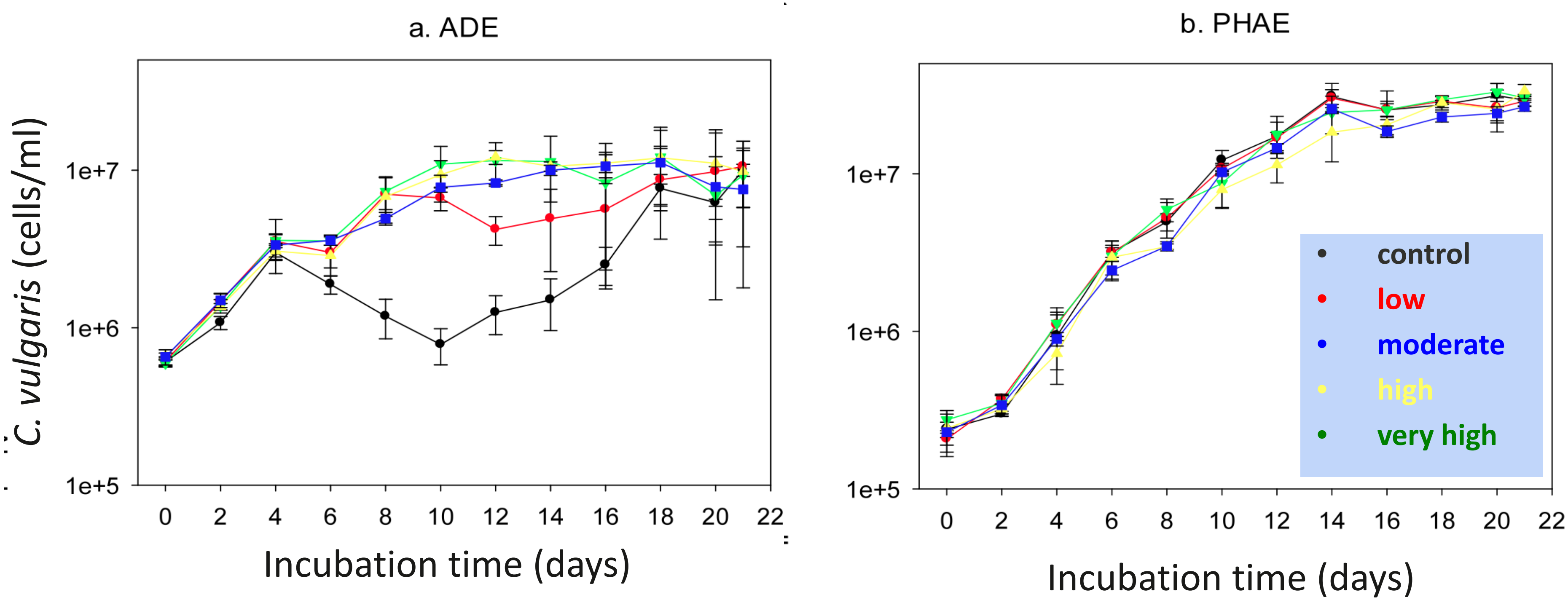
Treatment Effects on **ADE**



Treatment Effects on **PHAE**



Effect of treatment on algal growth

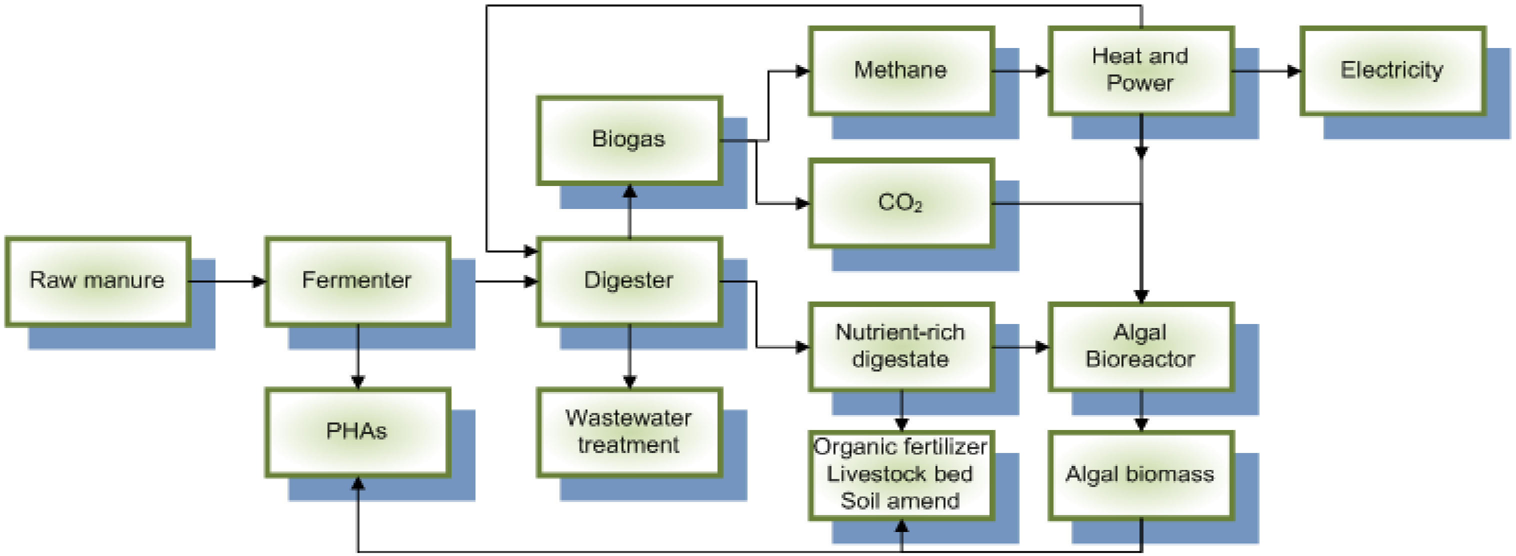


Conclusions

- Algal treatment of AD and PHBV reactor effluent resulted in
  - Up to 75% N removal, up to 60% P removal
  - 3x – 4x increase in cell yield when cultivated on PHBV effluent
- Nutrient/Carbon sequestration is dependent on
  - Effluent type, N species
  - Residual solids
  - Optical properties of effluents
    - These can be modified to influence algal growth rates
- Current work: determine effects of effluent properties, cultivation conditions, and pre-treatment strategies on algal biomass quality
  - Optimizing the algal component of the manure to commodities system for biofuels and/or bioplastics

Develop and deploy a web-accessible model to optimize the movement of carbon to PHBV & CH_4

- ***D****ecision-support for Digester-****A****lgae* ***I****nteg****R****ation for* ***I****mproved* ***E****nvironmental and* ***E****conomic* ***S****ustainability (DAIRIEES)*, a web-based model
- Enhance understanding of essential processing steps needed for scale up to commercial levels



Acknowledgements

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Growth parameters (ADE vs. PHBV)

	Anaerobic Digester Effluent (ADE)			Polyhydroxyalkanoate Reactor Effluent (PHBV)		
	5%	10%	20%	5%	10%	20%
Exponential growth rate (day^{-1})	0.4 -0.04	0.36 -0.01	0.48 -0.03	0.46 -0.01	0.33 -0.01	0.42 -0.03
Days of exponential growth	4	6	4	8	12	4
Final 21 day cell count ($cells \cdot mL^{-1}$)	10,016,667 (883,648)	10,116,667 (625,167)	12,683,333 (5,998,819)	29,300,000 (2605,763)	40,416667 (2,729,621)	13,983,333 (625,167)
Final cell count per mg N loading (cells/mg)	162.5 (13.7)	121.1 (24.2)	132.1 (71.3)	1,139.0 (143.8)	376.0 (24.8)	104.1 (11.2)
Final 21 day biomass ($g \cdot L^{-1}$)	0.89 (0.08)	1.39 (0.16)	2.23 (0.54)	0.67 (0.05)	1.07 (0.23)	1.57 (0.01)

Mean values (standard deviation), n=3. N.D. = none detected.

PHBV: longer log phase

PHBV: greater algal cell yield

C fixed: 0.6 to 2 g/L of biomass ≈ 0.4 to 1.6 g of C fixed L^{-1}

